Ebert Composites Corporation

New Composite Structures to Replace Wood and Steel Utility Poles and Towers

During the early 1990s, population growth placed extensive demand-driven pressure on existing power lines, but electric utilities were hampered in their efforts to meet this demand due to the high cost and growing environmental concerns. For example, steel towers were expensive to manufacture, required large teams and heavy machinery to install, demanded anti-corrosion treatments, and weighed too much to transport by helicopter into wooded areas. Wood poles were not desirable because chemicals from anti-decay treatments could leach from the poles into the water supply and sometimes violated environmental restrictions. Ebert Composites Corporation proposed to radically change the design and manufacture of utility towers and poles to make them cheaper to manufacture, longer lasting, and more environmentally friendly. As an early-stage company, however, Ebert did not have the resources to pursue the high-risk research needed for such an innovative product without jeopardizing the company's survival. In 1994, the company applied for and received funding from the Advanced Technology Program (ATP) to develop its innovative composite structure production process.

Through the ATP award, Ebert created its in-line computer-numerical-controlled (CNC) process to produce machined, pultruded composite lineal structures that were light enough, strong enough, and inexpensive enough to replace existing steel towers. The technology led to a significant reduction in manufacturing time; one leg of a typical steel structure, for example, took 16 hours to manufacture compared to 25 minutes for Ebert's composite pultrusion product. Rather than hiring trucks and maneuvering steel poles into densely wooded areas, Ebert's designs were light enough to be rapidly installed with a helicopter, reducing installation time in wooded areas by several days. Another product, the Ebert utility pole, was ultimately commercialized through a joint venture formed with a company in 1998. The utility pole, which has generated commercial success for the joint venture, provides improved durability, strength, and environmental soundness, as well as reduced costs.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
* * *

Research and data for Status Report 94-02-0025 were collected during July - September 2001.

Steel Towers and Wood Poles Are Costly and Environmentally Questionable

For the past 20 years, the electric power industry has been primarily a cost-driven business, with capital equipment as its biggest expenditure. Bringing electric power to new communities often required stringing power lines from the plant through wooded areas or across other difficult geography. As a result, new roads had to be built to deliver materials and labor because the traditional steel utility towers were too heavy to transport by helicopter. Further, wooden structures were not desireable because the environmentally hazardous chemicals used to treat the wood against rotting could leach into the water supply.

Revolutionary Manufacturing Process for Composite Materials Funded by ATP

Ebert's concept (a corrosion-resistant, lightweight, nonconductive structure) seemed to be an ideal substitute for the steel lattice structures typically used to support large transmission power lines. Moreover, Ebert's existing integrated manufacturing system could be used to manufacture these structures. In this process, filaments from large fiber spools are drawn to a heating die wherein the fibers and resins are molded to the appropriate shape. A clamping system downstream of the heating die pulls the fiber from the spools at the appropriate speed according to the job's specifications. Resin is injected through an impregnation system, impregnates the fiber bundles, and forms the appropriate shape within the heating die. Next, the pultruder pulls cured lineals that are properly molded and are machined by a multi-axis and synchronous computer-numerical-controlled (CNC) machine. The lineals are bar-coded for quick snap-together construction. Using a first-generation system, Ebert created a prototype process through a contract with two local utilities during the mid-1990s. Ebert's CNC machine produced a structure that was nearly 50 percent lighter than steel. The structure also had lower life cycle and installation costs and fewer environmental risks than steel towers or wooden poles.

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Though the structural concept was sound, a number of problems remained as barriers to the effective production of Ebert's composite structure. First, the company had to coordinate the process control of pultrusion, machining, and bar-coding in order to develop temperature-compensation techniques so that the product could be machined at elevated temperatures. Second, Ebert had to develop specific multi-axis machining techniques to meet the precise shapes required in construction. Because of these remaining technical challenges, the risks of Ebert's technology were very high; risks were driven even higher by Ebert's status as an early-stage company without a sizeable research and development budget. Corporate partners would not fund the research, venture capitalists did not want to take on this high level of risk, and Ebert could not afford to fund the project internally.

Ebert's composite material technology has superior weight bearing properties over traditional steel lattice angles.

Project success could potentially lower costs across the construction industry as well as reducing chemical hazards in the environment. Therefore, in 1995 ATP awarded Ebert $1 million in cost-shared funds. Ebert's technology could give a wide range of construction industries access to structural elements whose weight-bearing properties were superior to traditional steel lattice angles. These elements offered an innovative system of structural parts for easy-to-assemble, large-scale frame structures. In addition to the geometric advantage, Ebert's product could provide life-cycle cost savings and environmental impact improvements that would help to alleviate demand pressures for electricity.

Ebert hoped that, after further research and refinement, the CNC machine could produce perfectly shaped lineals ready for snap-and-build applications without additional machining, while retaining their cost and environmental advantages. The goal was that computer-assisted designs for utility towers could become a reality on the first attempt.

The cost savings from using composite structures throughout the life cycle of a tower is currently unknown because the product has not been on the market long enough to evaluate its full life cycle. However, data gathered prior to ATP funding suggested that composite pultrusion towers would be significantly less expensive to construct, on an installed basis, when compared to traditional structures. Moreover, composite tower insulators do not need the semi-annual water washings that steel towers require to prevent corrosion tracking, adding to life-cycle/maintenance cost savings.

Ebert Solves Technical Issues Relating to CNC Pultruded Lineals

Ebert faced several expected technical challenges during this project, as well as two additional, unexpected challenges that threatened project success. The company ultimately overcame each challenge.

First, Ebert needed to develop a CNC demonstration unit that could achieve the manufacturing goals before the construction and installation benefits could be realized. Typically, high-speed, five-axis CNC machines use a collection of gears that limit production speed and flexibility. This problem could only be resolved by using a different drive mechanism. Through the ATP project, Ebert researched and designed a new "direct-drive," high-speed design using torque motors. This efficient configuration allowed 40,000-rpm spindles to be mounted to the CNC gantry controlled by the CNC computer. This design was very different from all available five-axis CNC machines and represented a major breakthrough in the cost, simplicity, and high-speed performance of state-of-the-art CNC machines.

ATP support enabled Ebert's research to advance years ahead of where it would have been otherwise.

Second, Ebert needed to synchronize the machining process so that the final product was pulled out of the die at the same speed as the pultrusion process. If the speeds were different, the machine would not function properly. Prior to the ATP project, no synchronization of composite pultrusion machines had been attempted, with the exception of a "flying cut-off saw machine." Since the saws could not use digital positioning, their cuts were inaccurate and could not be used in Ebert's process. Synchronization attempts during the life of the ATP project were not able to meet the exacting requirements for this machine. However, due to partial technical successes overall, the company was able to continue its efforts after the end of the ATP-funded project. Within one year of project completion, Ebert had developed a linear belt encoder that senses the linear travel of a pultruded composite element and feeds this signal to the CNC controls. Since the belt does not slip on the composite, any sudden speed change by the pultrusion machine is digitally transferred to the control so that the fiber feed speeds can be adjusted accordingly. This was the first CNC machine to be coupled electronically and accurately to the speed of a pultruded lineal.

Third, Ebert needed to design an open architecture control system that allows coordinated control of variable sequential pultrusion and machining operations. Open architecture simply was not available for a five-axis CNC machine. Ebert required an open architecture system to adjust both speeds for different lineals and temperature changes so that the lineal could be machined to the correct "cooled" dimension even though the lineal was at an elevated temperature. To solve this problem, Ebert used PC-based hardware to adapt a multi-axis controller from Delta Tau, a motion controller provider, for the CNC machine. The controller was very flexible and allowed even more machining heads than the five axes used to date. Using the five axes, Ebert met its goal of obtaining reproducible machining tolerances that were accurate to 0.001 inches. Detail this fine was critically important in allowing Ebert's machine to work seamlessly with computer-assisted design equipment.

The fourth technical problem stemmed from limits in existing computer-coding technology for CNC manufacturing. Ebert needed to develop advancements in computer-code capability to permit back-to-back machining of detailed composite parts with no interruptions. This would allow for a continuous production process that saves the time and money otherwise used for resetting and refeeding traditional machines. The biggest challenge was meeting the significant memory and storage requirements necessary to save and process sequential CNC code for many different components, while enabling precise end-to-end automation. Ebert devoted significant programming time to designing memory and coding systems for CNC manufacturing, ultimately producing a workable software set.

Company executives commented that without ATP support, this technology would not have progressed as quickly as it did. At the end of the ATP-funded project, executives believed that the funding enabled Ebert's research to advance years ahead of where it would have been otherwise.

Ebert Enters Into Joint Venture To Commercialize its Products

Ebert's commercialization efforts, which began after the conclusion of the ATP-funded project, are ongoing as part of the company's joint venture with Strongwell Corporation. Ebert first met Strongwell, the world's largest pultruder, at an ATP composites-technology-funded-projects meeting. That meeting resulted in Strongwell-Ebert, LLC, a 50-50 joint venture formed in April 1998. Strongwell provided capital and facilities in Bristol, Virginia, and Ebert provided CNC machinery, materials, knowledge, and licenses to its patents.

Advances in manufacturing have reduced a structure's production time from approximately three days to less than two hours.

The joint venture is now producing composite poles at a price that is competitive with traditional poles. The advances in manufacturing have reduced a structure's production time from approximately three days to less than two hours. The lighter poles are also installed more quickly and easily, resulting in cost savings of 50 to 60 percent compared with traditional steel poles.

In 1999, Ebert's electric utility tower earned the prestigious Charles Pankow Award for innovation in civil engineering from the Civil Engineering Research Foundation. In addition, company engineers have published papers in the Society of Manufacturing Engineers and Composite Manufacturing journals and have presented papers at the Composite Manufacturing and Offshore Operations conference.

In 2000, Strongwell purchased the joint venture from Ebert Composites and currently manufactures the products through an Ebert license of patents and technology.

Conclusion

ATP funded Ebert's successful efforts to develop a process to manufacture composite construction materials for the electric utility industry that are stronger, lighter, and less expensive to manufacture and maintain than steel. The use of these materials for utility poles requires less manufacturing and installation time and provides improved durability. The composite poles also have less negative impact on the environment than traditional materials. After the ATP project, Ebert formed a joint venture with Strongwell. The Strongwell-Ebert, LLC, joint venture commercialized an award-winning product for the electric utility industry.

PROJECT HIGHLIGHTS
Ebert Composites Corporation

Project Title: New Composite Structures To Replace Wood and Steel Utility Poles and Towers (Synchronous In-Line Computer-Numerical-Controlled (CNC) Machining of Pultruded Composite Lineals)

Project: To create a process to manufacture composite lineal structures for the electric utility industry that are stronger, lighter, and cheaper to assemble and maintain than steel structures.

Duration: 1/23/1995-5/30/1997
ATP Number: 94-02-0025

Funding (in thousands):

ATP Final Cost	$1,032	77%
Participant Final Cost	303	23%
Total	$1,335	

Accomplishments: This ATP-funded program met its technical goals. Ebert's five-axis CNC machine is capable of accurately tracking and machining composite lineals on a continuous basis. This enabled a 97-percent reduction in manufacturing time for electric utility towers compared to the manufacturing time for typical steel structures. Highlights of the project's accomplishments are:

- Development of synchronous CNC equipment that machines composite pultrusions quickly, accurately, and to precise tolerances.
- Realization of cost savings from using torque motors and linear ball screws to eliminate costly transmission-drive gearing. The 40,000-rpm spindle mounts directly on the end of the machining head, providing the necessary tip speed to machine composites.
- Incorporation of a PC-based, open architecture controller to allow full control of all five axes of motion with flexible programming options, such as temperature compensation and the ability to store a large volume of CNC code for multiple operations.
- Creation of a belt encoder to track the pultruded part and feed a velocity signal to the speed control, enabling the CNC process to be installed with all commercially available pultrusion machines without sacrificing fiber speed or machine accuracy.
- Use of the knowledge gained to improve a 50-axis CNC machine, representing a tenfold increase over the number of axes available at the end of the ATP-funded project.

This ATP-funded project benefited from the following patents:

- "High shear strength pultrusion"
(No. 5,597,629: filed January 26, 1995, granted January 28, 1997)
- "High shear strength pultrusion"
(No. 5,795,424: filed January 26, 1997, granted August 18, 1998)

Ebert Composites also earned a number of distinctions for civil engineering achievements, such as the Charles Pankow Award for innovation in civil engineering from the Civil Engineering Research Foundation (1999). The joint venture shared its ATP-project knowledge through industry publications and presentations, such as the following:

- Publication in a Society of Manufacturing Engineers journal (1999)
- Presentation of a paper at the Composite Manufacturing and Offshore Operations conference (2000)

Commercialization Status: Through Strongwell-Ebert, LLC, Ebert Composites Corporation's technology has been commercialized into composite structures for electric power poles and lattice towers. These products are sold and used throughout the United States within the electric power industry. While exact sales and market share information is proprietary for this privately held company, sales are more than sufficient to fund operations and future research and development projects. When the 50-axis machine is ready, the extremely intricate poles will expand pultruded lineals' utility, and the environmental benefits will make these products an even more attractive option to replace steel towers and wooden poles.

Outlook: As pultruded lineals increase in detail, they will replace numerous structures in diverse industries. The limiting factor is the required detail in lineal shape (a factor that will be overcome with the multi-axis CNC machining center). The outlook for this technology is outstanding within the electric utility industry and could possibly revolutionize other industries as well.

Composite Performance Score: * * *

Number of Employees: 12 at project start, nearly 100 through the joint venture operations as of September 2001

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